MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

DETERMINATION OF A METHODOLOGY FOR CONDUCTING A COST EFFECTIVENESS ANALYSIS STUDY OF THE INTEGRATION OF LOW OBSERVABLES (LO) AND ELECTRONIC WARFARE (EW) IN AIR VEHICLE (AV) DESIGN (U)

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The advent of decreasing defense budgets coupled with acquisition reform efforts and the high cost of advanced technology applications has produced a definitive need for a methodology to assess the cost benefit of aircraft performance specifications. This methodology must be an iterative process that allows the user to perform design tradeoffs and assess their respective impacts to military utility and cost. This thesis details the approach for conducting an Analysis of Alternatives (AoA), a.k.a. Cost and Operational Effectiveness Analysis (COEA), study to assess the cost-performance tradeoffs of applying Low Observable (LO) technology and Electronic Warfare (EW), either exclusively or mutually, to an aircraft design. The methodology recommends the use of engagement level models and simulations (M&S) coupled with mission level M&S in the absence of a single integrated M&S product. The engagement level analysis is necessary to support high fidelity data requirements that are used by the mission level program to gather relevant measures of effectiveness (MOE) required for the mission effectiveness evaluation. These MOE's are then integrated with corresponding cost data in an effort to examine cost-performance characteristics. Iterative performance modifications can be similarly evaluated in an effort to establish trends, which will assist the user in assessing cost-performance tradeoffs.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Low Observables, Electronic Warfare, Electronic Counter-Measures)

KEYWORDS: Low Observables, Radar Cross Section Reduction, RCS, Electronic Counter-Measures, ECM, Modeling and Simulation, M&S, Mission Level Modeling and Simulation, Enhanced Surface-To-Air Missile Simulation, ESAMS

THE ANALYSIS OF COMPONENTS, DESIGNS, AND OPERATION FOR ELECTRIC PROPULSION AND INTEGRATED ELECTRICAL SYSTEM

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The surface combatant of the 21st century will be designed to support a myriad of tasks requiring greater flexibility and endurance while keeping construction, maintenance and operating costs to a minimum. As a

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result the design of a surface combatant will depart from today's standards and philosophies. One option is the use of an electric propulsion system that can be integrated with the other ship's electrical loads. Electric propulsion operating with an Integrated Electrical System has many advantages that will fulfill the requirements of future surface combatants.

This study provides the historical background, the supporting issues, components, and architecture of electric propulsion systems and the integrated electrical system. Technical information on various component types and issues that influence the design considerations of an electric propulsion system and integrated electrical system to meet the requirements of a surface combatant are addressed. The areas of study are prime movers, generators, frequency converters, motors, ship's service electrical distribution, auxiliary electrical loads, and system control.

The designer and operator of the surface combatant of the 21st Century can better understand the application of an electric propulsion system and an integrated electrical system from the accrued information on components, system architecture, and system control herein.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Electric Propulsion, Ship's Propulsion, Prime Movers, Generators, Synchroconverter, Cycloconverter, Pulse Width Modulation, Synchronous Motors, Synchronous Machine Ship's Service Electrical System, Integrated Electrical System, Ship's Service Distribution System, Ship's Service Electric Generator, Six-Pulse, 12-Pulse, DC ZEDS, Electro-Magnetic Aircraft Launching System, Pulse Energy Weapons, Power Electronic Devices

AUTOMATIC EXTRACTION OF THREAT SIMULATOR CRITICAL PARAMETERS VERSION 3.0 (U)

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Anti-ship cruise missiles (ASCMs) continue to be a poignant threat to the surface combatants of the U.S. Navy. OPNAV 913 directs the Effectiveness of Navy Electronic Warfare Systems (ENEWS) program to develop hardware-in-the-loop (HIL) simulators to support the research, development, test and evaluation of the most critical threats of interest. To ensure that the ASCM simulator accurately represents the threat missile, OPNAV 913 has recently established the Navy Unique ASCM Simulator Validation Working Group. One part of the validation process is to run the ASCM simulator through a battery of anechoic chamber characterization tests in order to determine the simulator's performance. The ASCM simulator's Electronic Warfare Integrated Reprogrammable Database (EWIRDB) parameters can easily be extracted from the characterization results using computer algorithms that automatically analyze the data. Comparing the corresponding parameters with the EWIRDB intelligence entries then provides one technique for measuring the performance of the ASCM simulator. This thesis describes a novel set of algorithms that extract 32 new EWIRDB parameters from characterization data, of which 29 are related to pulse repetition interval (PRI) characteristics, two are related to velocity memory and one is related to azimuth accuracy. FFT and autocorrelation function techniques to compute PRI mode parameters with periodic and staggered components are developed. Also, a graphical user interface (GUI) in a Matlab environment and a modular architecture allowing for straightforward software development and maintenance are discussed. The performance of a number of significant threats are numerically evaluated as a function of the test results.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation, Computing and Software

KEYWORDS: ASCM Simulators, Automatic Extraction of Threat Simulator Critical Parameters, GUI, Algorithms, EWIRDB Parameters

FEASIBILITY ANALYSIS FOR A SUBMARINE WIRELESS COMPUTER NETWORK USING COMMERCIAL-OFF-THE-SHELF COMPONENTS

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This thesis investigates the feasibility of deploying wireless local area networks (WLANs) onboard submarines. Installing wireless networks on submarines is intended to improve the productivity of the crew by leveraging the superior connectivity and data processing capabilities of commercial-off-the-shelf (COTS) wireless networking technologies. Areas specifically targeted for improvement are damage control communications and watchstander log taking.

In this thesis, the effects on wireless communications of the submarine's mostly metallic construction are examined along with potential mitigation methods. The overall requirements and specifications for a submarine wireless network are also derived. These constraints are then matched against the capabilities of existing commercial products in the mobile computing and wireless networking industries. Finally, a proof of concept system is developed and evaluated in both laboratory and submarine environments. Testing results demonstrate that a low-cost, high-performance WLAN for use in submarines is achievable using existing technologies. Additionally, recommendations are provided as to which evolving technologies have the most promise for future system improvements. This thesis work is the first part of an ongoing project that is tasked to specify, design, prototype, and test a wireless local area network for installation in the New Attack Submarine (NSSN).

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications, Other (Wireless Communications)

KEYWORDS: Wireless Local Area Networks, Spread Spectrum, PDAs, Handheld Computers

AN ANALYSIS OF LIMITATIONS IN ACTIVE CANCELLATION OF RADAR SIGNALS

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Acoustic noise suppression has been achieved by rebroadcasting a phase-inverted copy of an incident signal, such that the two signals cancel. The same effect applies in theory to electromagnetic signals, allowing the cancellation of radar signals. This effect would supplement existing "stealth" technologies. The electromagnetic equivalence theorem provides for a straightforward theoretical analysis, and several numerical analyses demonstrate cancellation on simple wire models. The limitations of the cancellation are covered with respect to bandwidth, canceler spacing, and two canceler unit failure (error) modes. Successful cancellation is demonstrated for two canceler densities up to approximately 50 MHz, and a significant reduction in canceler effectiveness results when the two failure modes are tested.

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DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Sensors

KEYWORDS: Radar, Electromagnetic Field Cancellation, Radar Cancellation, Scattering Analysis

USING THE PEBB UNIVERSAL CONTROLLER TO MODIFY CONTROL ALGORITHMS FOR DC-TO-DC CONVERTERS AND IMPLEMENT CLOSED-LOOP CONTROL OF ARCP INVERTERS

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The objective of this thesis is two-fold. The first goal is to expand the operational capabilities of the Ship's Service Converter Module control algorithm for a DC-to-DC converter using the Universal Controller. The second goal is to investigate the use of the Universal Controller to implement a closed-loop control algorithm for an Auxiliary Resonant Commutated Pole (ARCP) power inverter. These power electronic devices are central to the development of a DC Zonal Electric Distribution System (DC ZEDS) that is scheduled for application in the twenty-first century surface combatant (SC-21). The development of appropriate control algorithms is a key element to this design process. The Universal Controller is a digital controller that was developed by personnel at the Naval Surface Warfare Center (NSWC), Annapolis, Maryland. The basic operation of the Universal Controller and the Texas Instrument TMS320C30 microprocessor architecture are described, with emphasis placed on the system control algorithms.

Previous studies have encoded and successfully tested a closed-loop control algorithm for a DC-to-DC converter. In this research endeavor, this control algorithm is expanded to include various protection circuits and a Master/Slave paralleling scheme. Finally, a closed-loop control algorithm for the ARCP inverter is encoded and recommendations for future research are outlined.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Computing and Software

KEYWORDS: DC-to-DC Buck Converter, Auxiliary Resonant Commutated Pole Inverter, Universal Controller, Closed-Loop Control of Power Inverters, Texas Instruments TMS320C30

INTEGRATING DIGITAL SIGNAL COLLECTION AND PROCESSING INTO THE SH-60R NAVAL AIR MULTI-PURPOSE PLATFORM (U)

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The capability of the SH-60R helicopter to become a BGPHES platform combined with other IO capabilities is not planned at this time. The primary station for this aircraft will be approximately 200 nautical miles from the carrier and this position presents an opportunity for gathering intelligence. The SH-60R also possesses a unique capability in that it can relay communications and data directly to a ship via secure link. This thesis explores the possibility of incorporating a new architecture that could be adaptable for several mission scenarios. Signal processing necessary to support mission scenarios is introduced which could be incorporated into IW tactics. This thesis will begin by introducing the reader to the SH-60R aircraft and specific signal processing software. The reader will then be introduced to real world signals and the exploitation of them.

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DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronic Warfare

KEYWORDS: Digital, SH-60R, ELINT, COMINT, SIGINT, MARTES

PERFORMANCE ANALYSIS OF NONCOHERENT BINARY FREQUENCY SHIFT KEYING USING EQUAL GAIN COMBINING AND POST DETECTION SELECTION COMBINING OVER A NAKAGAMI FADING CHANNEL

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In this thesis, the performance of a noncoherent Binary Frequency Shift Keying (BFSK) receiver using Equal Gain Combining (EGC) and Post Detection Selection Combining (PDSC) techniques over a frequency nonselective and slowly Nakagami fading channel is investigated.

Analytical and numerical results obtained for EGC are compared to those obtained for first order PDSC (PDSC-1), second order PDSC (PDSC-2), and third order PDSC (PDSC-3).

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Nakagami Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGC), Post Detection Selection Combining (PDSC)

INVESTIGATION OF HIGH FREQUENCY SHIP RADAR CROSS SECTION REDUCTION BY MEANS OF SHAPING

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The objective of this thesis is to investigate and evaluate the effectiveness of ship radar cross section (RCS) reduction in the high frequency (HF) band by means of shaping. The study is based on a computer simulation which uses the method-of-moments to compute the RCS of a number of conventional and shaped ship geometries. It was found that a ship with canted deckhouse walls and a standard hull had little reduction in RCS relative to a conventional ship. This result shows that shaping is not as effective at these frequencies (3-30 MHz) as it is in the optical region. The hull is the major contributor to RCS near broadside. Shaping the hull did reduce the RCS slightly for the frequencies and elevation angles investigated.

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: HF Radar, Ship, RCS, Method-of-Moments, CAD

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MATLAB IMPLEMENTATION OF A FOURIER APPROACH TO OPTICAL WAVE PROPAGATION

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This thesis explores a MATLAB implementation of a Fourier transform approach to model and predict transient optical wave propagation through free-space. A three-step approach is adopted in this study. First, the mathematical development establishes the importance of the total impulse response as the Green's function, meeting the boundary conditions and solving the wave equation. Second, a MATLAB program is developed to simulate the mathematical model by computing and displaying the graphical representation of an optical wave's spatial distribution on a plane at a given distance from a spatially filtered source. Third, a circular excitation function is used to verify the program and then the results of another three excitations, namely the square, circularly truncated Gaussian and circularly truncated Bessel functions are similarly generated. The effort of this thesis provides an inexpensive means to analyze a transient optical wave propagation of a spatially filtered optical source.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Green’s Function, Spatial Impulse Response, Diffraction, MATLAB

COMPARISON OF SUPER RESOLUTION ALGORITHMS WITH DIFFERENT ARRAY GEOMETRIES FOR RADIO DIRECTION FINDING

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The objective of this thesis is to investigate and evaluate the effectiveness of modern estimation methods with different array geometries as they apply to the problem of bearing estimation. These algorithms were selected from those that apply to the multidimensional case, including MUSIC, PHD, minimum norm, and Capon’s beam-former. These four techniques are chosen based on their high resolution capability, and their ability to deal with three-dimensional non-uniform arrays and can estimate both azimuth and elevation angle of arrival(AOA). Computer simulations were run for linear arrays, circular arrays, and combinations of the two. The test conditions included: (1) two closely spaced emitters and (2) various levels of additive white Gaussian noise.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors

KEYWORDS: Direction Finding, Antenna Array, Superresolution Techniques

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A CENTRALIZED TIME-SPACE-POSITION INFORMATION ARCHITECTURE FOR ABSOLUTE TARGETING IN HIL CAPTIVE-CARRY MISSILE SIMULATOR EXPERIMENTS (U)

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Captive-carry electronic warfare experiments are performed using hardware-in-the-loop (HIL) missile simulators in order to determine the effectiveness of the targeted platform's electronic attack (EA) self-protection system. To determine the EA effectiveness, these experiments require that the position of the captive-carry aircraft and other moving objects on the test range (e.g., chaff) be known precisely as a function of time. Distributed Sensor, Time-Space-Position Information systems have been used to provide this information and typically consist of two or more measurement sensors located at some distance from each other with each sensor making a measurement of the target's angle and range. These systems are very complex since they involve multiple hardware installations, complex mathematical computations for extraction of coordinate information, synchronization of multiple sensor measurements, and independent calibration of several different measurement stations. Consequently, the accuracy of the resolved target positions can be severely degraded. This thesis presents a Centralized Time-Space-Position Information Architecture for Absolute Targeting that accurately displays in geodetic coordinates, a complete pictorial presentation of a field test experiment using only the onboard sensors of the captive-carry aircraft. By successfully synchronizing and integrating data from the Inertial Navigation System (INS), the Global Positioning System (GPS), and the targeting information from several distributed HIL missile simulators, accurate displays of the test range results are provided for easy interpretation and analysis. The architecture presented also provides both manual and automatic tagging routines to analyze and evaluate specific points of interest during a particular field test scenario (e.g., missile transfers lock to decoy). Actual captive-carry field test results using anti-ship cruise missile HIL simulators are presented in order to demonstrate the advantages of this approach.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Modeling and Simulation

KEYWORDS: Absolute Targeting, ASCM HIL Simulators, Captive-Carry Field Tests, Sensor Synchronization, GPS, INS, Track Tagging

AN ANALYSIS OF A BROADBAND MULTI-CARRIER CODE DIVISION MULTIPLE ACCESS (CDMA) CELLULAR COMMUNICATIONS SYSTEM

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The integration of land, sea, and air forces within the littoral environment will require fading resistant, high data rate, non-exploitable communications. The large volumes of video and data information, i.e. Internet access, video teleconferencing, and data transfer, required to support the war fighter within a Joint Task Force demands technologies that reduce the interference imposed by poor terrestrial and atmospheric conditions. In order to minimize the effect of frequency-selective fading that occurs in these conditions and to provide high data rate communications, this thesis presents the analysis of a broadband cellular system featuring a multicarrier, code division multiple access (CDMA) method. The system designed complies with Federal Communication Commission broadband cellular standards and uses CDMA to reduce the probabilities of detection and interception as well as providing for multiple access, which in conjunction with the multicarrier approach enables on demand access to high data rate communications.

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DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Modeling and Simulation

KEYWORDS: Littoral Communications, Analysis, Cellular, CDMA, Broadband, Multicarrier

PERFORMANCE ANALYSIS OF BINARY FSK SIGNALS WITH L-FOLD DIVERSITY SELECTION COMBINING TECHNIQUES IN A NAKAGAMI-M FADING CHANNEL

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This thesis investigates the performance analysis of a non-coherent Binary Frequency Shift Keying (BFSK) receiver using Selection Combining techniques over a frequency non-selective, slowly fading Nakagami channel. These techniques are independent of the number of diversity branches, so simpler receivers can be employed.

First order selection Combining (SC), second order Selection Combining (SC-2), and third order Selection Combining (SC-3) techniques are evaluated and compared to each other. Numerical results show that the performance improves as the order of Selection Combining techniques increases.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Nakagami –M Fading Channel, Diversity Combining Techniques, Selection Combining (SC)

A WIDEBAND MULTICARRIER CODE DIVISION MULTIPLE ACCESS (CDMA) CELLULAR COMMUNICATIONS SYSTEM

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The demand for mobile access to high data rate communications services such as video teleconferencing, Internet access, or file transfer continues to grow rapidly for a wide variety of military as well as commercial applications. Existing mobile narrowband cellular communications systems do not have sufficient bandwidth to support high data rate applications. Simply increasing the bandwidth of existing cellular systems to support higher data rates results in a significant degradation in signal quality and reliability due to frequency selective fading. The wideband cellular system design presented in this thesis features a multicarrier approach that minimizes frequency selective fading for very high data rate applications and a dual mode reverse channel that facilitates efficient utilization of bandwidth for low to very high data rate applications.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Cellular, CDMA, Wideband, Multicarrier

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A DIGITAL IMAGE SYNTHESIZER FOR INVERSE SYNTHETIC APERTURE RADAR (ISAR) COUNTER-TARGETING

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Inverse Synthetic Aperture Radar (ISAR) is a version of SAR that can be used operationally to image targets such as ships, aircraft, and space objects. It falls under the genre of imaging radars, since an ISAR image contains information on range, cross-range, and reflectivity (radar cross-section) of the target. Active deception, such as the use of false targets, requires special consideration against these types of radars. The purpose of this thesis is to study, design, and develop a hardware "digital image synthesizer" prototype using Field Programmable Gate Arrays (FPGA) capable of producing coherent false target images on such radars. The proposed hardware uses digital tapped-delay lines for time-interval (range gate) generation and the use of Doppler focussing and radar cross-section blocks for frequency and gain modulations respectively. The suite of simulation software, including a bit-and-architecturally true simulator, format conversion files, visual basic program and hardware are developed to demonstrate the concept of the digital image synthesizer. Moreover, the hardware results match those from the bit-and-architecture simulator's results closely.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Inverse Synthetic Aperture Radar, Countermeasure